Nanomagnetism and Polarized Soft X-rays

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One of the driving forces of today's magnetism research is the magnetic storage industry. Of interest are sandwiched magnetic sensors, spin valves, spin transistors and magnetic "media" consisting of ferromagnetic thin films and multilayers that can store information in nano-sized "bits". Scientific investigations in this area are concerned with the origin of magnetic coupling, spin transport across interfaces, magnetic properties of magnetic oxides, the complex magnetic structures which evolve when different kind of magnets for example antiferromagnets and ferromagnets are brought into contact and finally the time dependence of magnetic reversal processes. In today's devices, magnetic switching times are about one nanosecond. The future of the magnetic storage and memory technology is guided by "smaller and faster". It is dependent on new materials that are

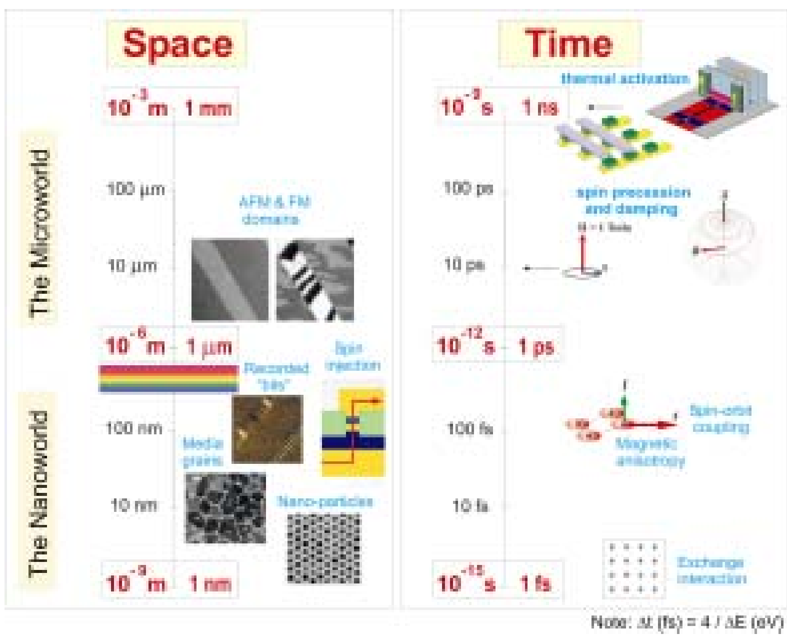

Fig. 1 Examples of magnetic devices used or under development in computer technology (left) and summary of present state of the art of timescales in technology and scientific methods to explore magnetic phenomena on ultra-fast time scales, needed for tomorrow's technology.

patterned or can self-assemble on the nanoscale and are magnetically stable at room temperature and on the developments of methods to manipulate the magnetization on the sub-nanosecond time scale. Apart from the fact that all these challenges mentioned above are of technological relevance they coincide with forefront questions in basic magnetism research, namely the static or dynamic properties of small magnetic elements on very short time scales.

The situation is summarized in Figure 1. It shows that especially on the time scale below 1ns our understanding of the relevant processes in magnets is still limited. Spin-orbit coupling, precessional switching and magnetic anisotropy are correlated with time scales between 100fs and 100ps, which are difficult to access experimentally. Using the time structure of the synchrotron and fast detectors like streak cameras will allow addressing these fundamental questions with high spatial resolution and elemental and magnetic sensitivity which will cover a relevant area in the spatial scale of figure 1 (5-50nm).

In summary x-ray absorption spectroscopy represents a unique possibility in addressing "small", "fast" and complex nanomagnets. The power of XAS is that it provides the possibility to address different material properties at the same time in a way which allows high spatial and temporal resolution:

It is able to characterize:

- Buried interfaces
- Different elements
- Different magnetic order (AFM/FM)
- Diluted or small magnets ($<0.005\mu B$) (~ 0.01ML)
- Time resolved switching behavior below 100ps eventually down to or even below 1ps.
- Spatial resolution currently 50nm in the future below 5nm.

So far x-ray absorption studies were often limited to soft x-rays. However recent efforts at the photon factory in Japan have shown that it is indeed possible to use PEEM with hard x-rays in transmission or absorption. This approach is in particular interesting for the APS, since it provides hard x-rays with excellent brilliance. The transmission PEEM setups allows for example to image the elemental distributions, structure and magnetism of thick biological samples with a spatial resolution of 100nm. On the other hand the absorption approach allows correlating magnetic and crystallographic domains by combining XMCD and EXAFS (EXAFS provides information on the local environment of an atom so that for example bcc and fcc Fe can be distinguished) on a length scale of 100nm and with an increased bulk sensitivity compared to soft x-ray PEEM.